THE MODIFIED STAR EXCURSION BALANCE AND Y-BALANCE TEST RESULTS DIFFER WHEN ASSESSING PHYSICALLY ACTIVE HEALTHY ADOLESCENT FEMALES

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ABSTRACT

Background: The modified Star Excursion Balance Test (mSEBT) and Y-Balance Test (YBT) are two common methods for clinical assessment of dynamic balance. Clinicians often use only one of these test methods and one outcome factor when screening for lower extremity injury risk. Dynamic balance scores are known to vary by age, sex and sport. The physically active adolescent female is at high risk for sustaining lower extremity injuries, specifically to the anterior cruciate ligament (ACL). Thus clarity regarding the use of dynamic balance testing results in adolescent females is important. To date, no studies have directly compared the various outcome factors between these two dynamic balance tests for this population.

Purpose: To determine if there was an association between the mSEBT and YBT scores for measured reach distances, calculated composite score and side-to-side limb asymmetry in the ANT direction in physically active healthy adolescent females.

Study Design: Cross-sectional study.

Methods: Twenty-five healthy, physically active female adolescents (mean age, 14.0 ± 1.3 years) participated. Reach distances, a composite score and side-to-side limb asymmetry for the mSEBT and YBT, for each limb, were compared and examined for correlation.

Results: There were significant differences and moderate to excellent relationships between the measured reach directions between the mSEBT and the YBT. Injury risk classification, based on limb asymmetry in the anterior reach direction, differed between the tests. However, the calculated composite scores from the two tests did not differ.

Conclusions: Performance scores on a particular reach direction should not be used interchangeably between the mSEBT and YBT in physically active adolescent females, and should not be compared to previously reported values for other populations.

Level of Evidence: Level 3.

Key Words: dynamic balance; lower extremity; movement system; screening tool.

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INTRODUCTION

Clinicians often use dynamic balance tests as a functional screen to identify athletes at-risk of injury, assess deficiencies following injury, and monitor rehabilitation progress.[1] The Star Excursion Balance Test (SEBT)[2,3] and Y-Balance Test (YBT)[4,5] are two reliable methods commonly used to clinically assess dynamic balance of the lower extremity. The time consuming eight-reach direction SEBT is often modified (mSEBT) to use only three reach directions: Anterior (ANT), Posteromedial (PM) and Posterolateral (PL).[6–8] The commercially available YBT apparatus (Move2Perform, Evansville, IL) is an instrumented version of the mSEBT, designed to improve repeatability and standardize test procedures.[4] Both the mSEBT and YBT simultaneously assess range of motion, flexibility, neuromuscular control and strength.[9] Within each test, there are a number of factors that can be reported and analyzed to assess lower extremity injury risk, such as the maximal reach distance measured in specific reach directions, a calculated composite score and side-to-side asymmetries in the anterior reach direction. Normative dynamic balance performance scores vary depending on the age, sex or specific sport played of the population.[10–16] Ankle injuries have been linked to a reduced reach distance in the PM direction in recreationally active college students,[17] while ankle sprains in high school and college football athletes were linked to a reduced reach distance in the ANT direction.[18] Normalized composite scores of less than 94% on the mSEBT in high-school female basketball players[14] and less than 86.5% in college football players[10] on the YBT indicate a significant risk of lower extremity injury. The likelihood of sustaining a noncontact lower limb injury is also increased with ANT reach distance asymmetry between limbs of greater than 4 cm in high school basketball players for the mSEBT[14] and Division I athletes for the YBT.[19]

Although the tests are very similar in nature, there are differences in the neuromuscular demands associated with each test. Within a healthy adult population reach distances and kinematic profiles differ between the mSEBT and YBT suggesting that the values between tests should not be used interchangeably.[20,21] With the variability in performance between subjects of different ages, sexes, and sport participation,[13,22] it has been suggested that normative data, and injury risk thresholds or cut-off scores should only be utilized for comparison with the specific test and participant population from which they were developed.[23]

Several investigations of adults and collegiate populations have noted differences within and between the SEBT and YBT,[20,21] however the literature lacks information regarding clinical dynamic balance tests for healthy active adolescent females. Although the relationship between the two dynamic balance scores for the adolescent female population is currently not known, it is of particular interest as this demographic carries a high-risk of sustaining lower extremity injuries, specifically to the anterior cruciate ligament (ACL) of the knee. Active adolescent females are four to six times more likely than males to sustain an ACL injury when participating in the same sports.[24] Additionally, young female athletes who return to sport following an ACL injury have the highest rate of re-injury (ipsilateral and contralateral) and are at 30-40 times greater risk of ACL injury compared to uninjured adolescents.[25] Clinicians may be incorrectly classifying young female athletes by inadvertently interchanging indices of performance between the mSEBT and YBT, or using injury-risk thresholds that have been established for a different population.

The purpose of the current study was to determine if there was an association between the mSEBT and YBT scores for measured reach distances, calculated composite score and side-to-side limb asymmetry in the ANT direction in physically active healthy adolescent females. As there are reported inconsistencies between the tests in an adult population, it was hypothesized that measured reach distances, a calculated composite score and side-to-side limb asymmetry for the ANT reach direction will differ between the mSEBT and YBT for physically active healthy adolescent females.

METHODS

Participants
Following approval from the University of Manitoba's Health Research Ethics Board (H2014:302), 25 recreationally active adolescent females with no

recent trauma to the lower extremity were recruited from the community to participate in this laboratory-based study. An a priori power analysis using data from a previous study of healthy recreationally active adults indicated that 22 subjects would be adequate to assess the mSEBT.[15,26] Inclusion criteria stated that volunteers were required to be female, 12-18 years of age, with no history of a lower limb musculoskeletal injury or concussions in the prior six months. Participants were excluded if they failed a standardized screening criteria protocol by having knee joint effusion, being unable to fully flex and extend the knee joint, demonstrating quadriceps lag with an active straight-leg raise, having quadriceps strength less than 75% of the unaffected leg on manual muscle testing or being unable to perform 10 consecutive pain free hops[27]. Informed consent was obtained from parents and participants prior to initiation of study activities.

Testing Protocol

Demographic information, such as age, leg dominance (based on the leg preference for kicking a ball) and sport participation were collected. Maturation status was determined using the self-reported pubertal maturation observational scale (PMOS).[28] The Physical Activity Questionnaire for Adolescents (PAQ-A) assessed physical activity level as a score of 1-5, 1 indicates a subject is minimally active and 5 extremely active.[29] Anthropometric data including height and weight were measured. The mSEBT and the YBT were completed according to previously described protocols,[4,9] and required subjects to perform testing while barefoot, maintaining their hands on their hips. For the mSEBT, subjects performed a series of single-limb squats using the non-stance limb to touch a point a maximum distance along designated lines on the ground (Figure 1). The mSEBT has been established as a reliable measure of dynamic balance in adolescents, with intra-rater intraclass correlation coefficients (ICCs) ranging from 0.82 to 0.87 and coefficients of variation ranging from 2.0% to 2.9%.[14] Lab pilot study results indicated inter rater ICCs ranged from 0.69 to 0.95 for the YBT reach directions and from 0.59 to 0.75 for the SEBT reach directions.

The YBT (Move2Perform, Evansville, IL) is a commercially available, instrumented product that is
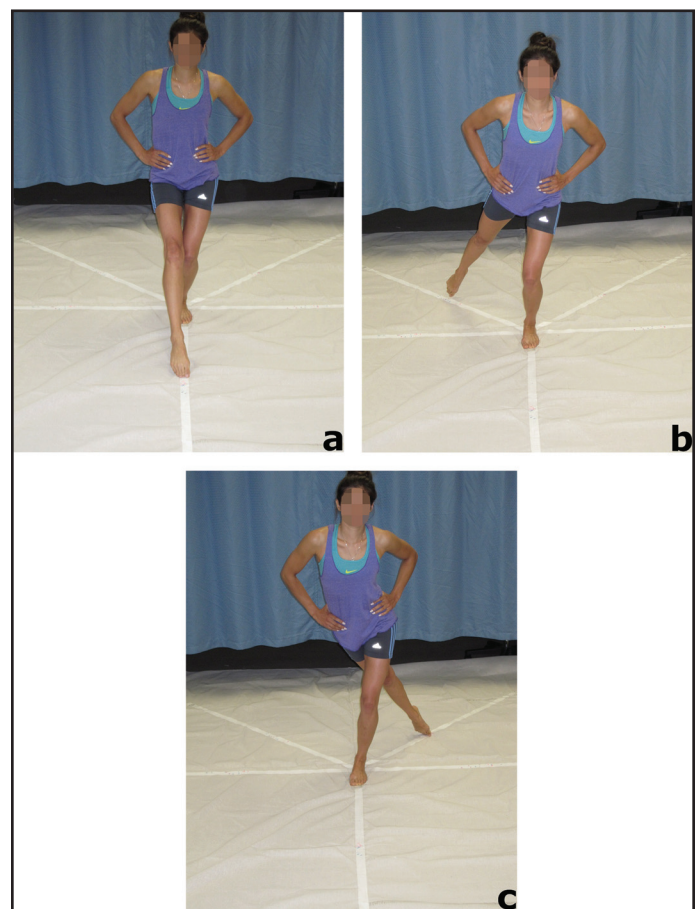
Figure 1. *Modified star excursion balance test (mSEBT) for the left stance limb. a: Anterior reach direction; b: Posteromedial reach direction; c:Posterolateral reach direction.*

used to evaluate the same three reach directions as the mSEBT (Figure 2). Subjects maintain a one-legged stance on an elevated stance platform from which three pieces of plastic pipe extend in the specific ANT, PM and PL directions. With the non-stance foot, participants push an indicator to a maximum distance along the pipe, marked with 0.5 cm increments. A previous study indicated that the YBT is a reliable method for assessing dynamic balance; within session inter-rater ICCs 0.54 to 0.82 and typical error values of 5.9% in children.[15]

For both tests, subjects performed the recommended four practice trials, in each direction prior to completing the three test trials on each limb.[4,8] A standardized order of testing was utilized, the right stance limb was measured first in the order of ANT, PM and PL. Testing was repeated in the same order for the left stance limb. If the subject removed their
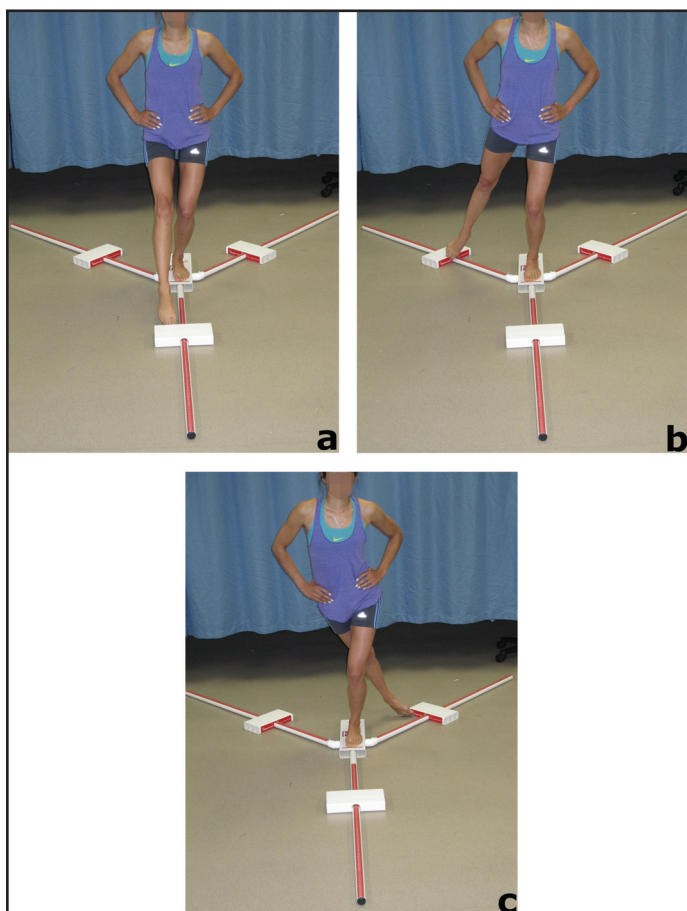
Figure 2. *Y-balance test (YBT) for the left stance limb. a: Anterior reach direction; b: Posteromedial reach direction; c: Posterolateral reach direction.*

hands from their hips, lost their balance or rested their reaching foot on the ground (mSEBT), kicked the reach-indicator plate to gain more distance (YBT), made contact with the ground on the reach or return to bilateral stance to gain balance, or lifted or shifted any part of the stance foot the trial was considered incomplete, and was repeated. The distance of the toe touch reached along each direction was marked and subsequently measured by an investigator for the mSEBT, while the most proximal edge of the reach indicator from the apex of the YBT was recorded.

The average of three successful test trails for each reach direction was used for data analysis. Limb length (LL) was measured from the anterior superior iliac spine to the most distal aspect of the ipsilateral medial malleolus in supine lying.[2] All reach distances were normalized as a percentage of the stance limb length using the formula [% = (excursion distance/LL) x 100]. A composite score, which is an average of all three reach distances, [Comp = ((ANT + PM + PL)/(3 x LL)) x 100] was also calculated for each limb. The absolute difference in the anterior reach direction distance (centimeters) between limbs was calculated to assess side-to-side asymmetry.[23]

Statistical Analysis

Descriptive data for both the mSEBT and YBT were calculated. Student paired t-tests were used to test the differences in reach distance scores between limbs and between the mSEBT and YBT. For the measured reach distance scores of the mSEBT differences of at least 6-8% are needed to feel confident that a clinical change in performance has occurred[26]. A Bonferroni correction alpha level of $p < 0.004$ (0.05/12) was used to compare the right and left limb because of the standardized test order of mSEBT followed by YBT, with the right limb reach directions always tested prior to the left limb. An alpha level of $p < 0.05$ was set for all other comparisons.[20] Effect sizes (Cohen's d) for the differences between the mSEBT and YBT scores were calculated with values less than 0.2, 0.21 to 0.79, and above 0.80 considered to represent weak, moderate and strong effects, respectively[30]. Pearson correlations and Bland-Altman assessments of agreement were used to compare performance on all three reach directions and the composite score for the mSEBT and YBT.[20,21,31] Correlation coefficients *(r)* of 0.25-0.49, 0.50-0.74, and 0.75-1.0 were considered to represent weak, moderate and excellent relationships, respectively.[32] The absolute difference in the anterior reach distance (centimeters) between limbs was assessed with Student paired t-tests, and compared with the established absolute side-to-side asymmetry injury risk cut-off value of greater than 4 cm.[14,19]

RESULTS

Demographic information and anthropometric data for participants are presented in Table 1. Results indicate that participants were predominantly post-pubertal adolescents with a normal BMI, right leg dominant and participated in a variety of sport activities. Separate 1-way analysis of variance based on maturation status and activity level indicated that these factors had no significant impact on dynamic

	Adolescent Females (N=25)
Table 1. *Participant demographic and anthropometric information, reported as mean ± SD, (95% confidence interval).*	
Age, y	14.0 ± 1.3 (13.5, 14.5)
Height, cm	163.1 ± 5.8 (160.7, 165.5)
Weight, kg	59.7 ± 15.5 (53.3, 66.0)
BMI, kg/m^2	22.3 ± 4.8 (20.3, 24.3)
Maturation status, n	
Pre-pubertal	3
Mid-pubertal	5
Post-pubertal	17
PAQ-A scale	2.9 ± 0.8 (2.6, 3.2)
Leg dominance, n	
Right	22
Left	3
Sports, n	
Basketball	1
Badminton	1
Baton	4
Dance	4
Cross country running	1
Gymnastics	2
Hockey/Ringette	5
Soccer	2
Softball	1
Tennis	1
Volleyball	3
BMI= body mass index; PAQ-A= physical activity questionnaire for adolescents	

balance reach direction scores, thus all subjects were grouped together for comparison of the tests. Comparison between the right and left limb indicated that there were no statistically or clinically significant between limb differences for either the mSEBT or the YBT. Statistically and clinically significant differences were observed between the mSEBT and YBT for all three measured reach directions. However, no significant differences were noted between the two procedures for the calculated composite scores or absolute asymmetry in the anterior direction (Table 2). Effect size calculations indicated that results were moderate to strong for all three measured reach distances, but weak for the composite score and absolute asymmetry. Pearson product-moment correlation coefficients between the mSEBT and YBT indicated a moderate to excellent relationship for all the measured reach directions, except the left limb in the anterior direction and the right limb in the posterolateral direction which both had a weak relationship (Table 3). Bland-Altman assessments of agreement between the mSEBT and YBT indicated that there was a bias between the three reach directions, however the calculated composite scores showed good agreement (Table 4). Two subjects had a greater than 4 cm absolute asymmetry in the anterior direction for the mSEBT and a different two subjects for the YBT (Figure 3).

DISCUSSION
This is the first report to compare the results from the mSEBT and YBT with a healthy physically active

Table 2. *Measured reach distances, calculated composite scores and absolute side-to-side asymmetry for the mSEBT and YBT, reported as mean $\pm$ SD, (95% confidence interval)].*

	mSEBT	YBT	p-Value	Effect Size †
Anterior direction, % limb length				
Right limb	94.9 ± 6.4 (92.2, 97.5)	65.6 ± 5.1 (63.5, 67.7)	< 0.01*	5.1
Left limb	96.1 ± 5.1 (94.0, 98.2)	57.0 ± 4.5 (55.1, 58.9)	< 0.01*	8.1
Posteromedial direction, % limb length				
Right limb	90.1 ± 10.8 (85.6, 94.6)	100.3 ± 7.0 (97.4, 103.2)	< 0.01*	1.1
Left limb	90.7 ± 9.2 (86.9, 94.5)	101.0 ± 6.9 (98.1, 103.8)	< 0.01*	1.3
Posterolateral direction, % limb length				
Right limb	83.2 ± 11.9 (78.3, 88.1)	98.5 ±7.8 (95.3, 101.7)	< 0.01*	1.5
Left limb	83.8 ± 11.9 (78.8, 88.7)	101.0 ± 7.9 (97.7, 104.3)	< 0.01*	1.7
Composite score, % limb length				
Right limb	103.5 ± 10.9 (99.0, 108.0)	102.1 ± 8.7 (98.5, 105.7)	0.62	0.1
Left limb	104.6 ± 10.7 (100.2, 109.0)	103.6 ± 8.8 (100.0, 107.2)	0.44	0.1
Absolute asymmetry, cm				
Anterior direction	2.1 ± 1.8 (1.4, 2.8)	2.0 ± 1.3 (1.5, 2.5)	0.68	0.1

mSEBT= modified star excursion balance test; YBT= Y-Balance Test
* p < 0.05
† Cohen's d

female adolescent population that is at significant risk for lower extremity injury. The main finding of this investigation was that measured participant scores for the three reach directions differ between the mSEBT and YBT. The anterior reach distance was greater for the mSEBT than the YBT, interestingly the posteromedial and posterolateral distances were less for the mSEBT than the YBT. In contrast, the opposing skewness of the measured reach directions resulted in similar values for the calculated composite scores for the tests. Also the established injury risk cut-off score of greater than 4 cm absolute asymmetry in the anterior direction identified different subjects at-risk of injury depending on the test method. As a consequence, caution should be used when comparing the results from the mSEBT and the YBT for a healthy physically active adolescent female population. When comparing these scores to the reported values for other populations within the literature, the test scores should remain exclusive to their specific population and test method.[20,21,23]

Demographic data confirmed that participants were young, physically active individuals engaged in

Table 3. *Correlation (r) between reach distances for the mSEBT and the YBT.*

	Pearson product-moment correlation coefficient (*r*)	p-Value
Anterior direction, % limb length		
Right limb	0.51	0.01[*]
Left limb	0.48	0.01[*]
Posteromedial direction, % limb length		
Right limb	0.54	0.005[*]
Left limb	0.66	<0.01[*]
Posterolateral direction, % limb length		
Right limb	0.41	0.04[*]
Left limb	0.65	<0.01[*]
Composite score, % limb length		
Right limb	0.61	0.01[*]
Left limb	0.79	<0.01[*]

Abbreviations: mSEBT, modified star excursion balance test; YBT, y-balance test
* p < 0.05

Table 4. *Bland-Altman assessments for agreement between the mSEBT and the YBT.*

	d	SD_{diff}	95% limits of agreement
Anterior direction, % limb length			
Right limb	29.3	5.8	17.8, 40.7
Left limb	30.2	4.7	20.9, 39.4
Posteromedial direction, % limb length			
Right limb	-10.2	9.1	-28.8, 7.7
Left limb	-10.4	7.0	-24.1, 3.3
Posterolateral direction, % limb length			
Right limb	-15.3	11.2	-37.3, 6.7
Left limb	-17.2	9.0	-34.9, 13.8
Composite score, % limb length			
Right limb	1.4	8.9	-16.0, 18.7
Left limb	1.0	6.6	-11.9, 13.9

D= mean difference; SD_{diff}= standard deviation of the difference

a wide range of sporting activities. This finding is important as it serves to extend the findings of other investigations on the YBT and mSEBT which focused on sport specific populations (such as basketball or soccer),[14,16] age specific populations (i.e., college-aged or young adults),[6,12,26] or specific competitive levels within sport (i.e., Division I or elite athletes).[11,19] Data presented are representative of a typical adolescent female population that participates in a variety of sporting activities and is nearing or has recently reached physical maturation. Anthropometric data also help to confirm that our adolescent females were representative of a healthy population that included individuals with various body types (tall/short; thin/muscular, etc.). Again, this finding serves to enhance the overall generalizability of our results to a broad population of adolescent females. Clinical measures of dynamic balance are a
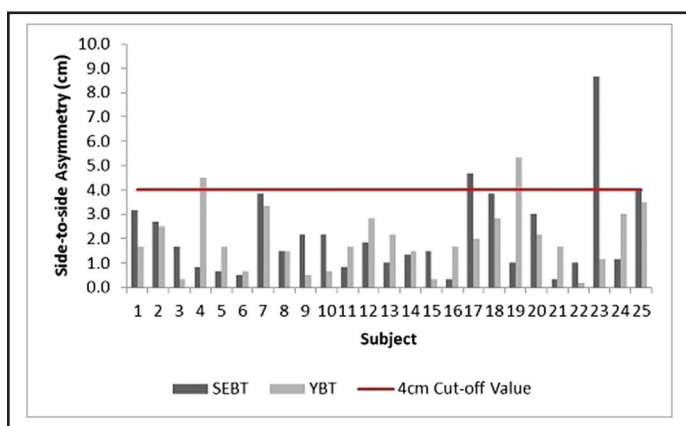
Figure 3. *Absolute side-to-side difference in the anterior reach direction.*

critical component of pre-participation screening in this population. If clinicians can accurately identify healthy adolescent female athletes who may be at an increased risk of sustaining lower extremity injuries, they can then advise and implement intervention strategies to address the factors associated with the epidemic of lower extremity injuries (especially to the ACL) seen in this population.

Two previous studies compared performance on the SEBT versus YBT for healthy active male and female adult populations. For reach in the anterior direction, both studies found a difference between the SEBT and YBT.[20,21] One suggested that disparities in posture control strategies may be responsible for the differences between the tests, and hypothesized that the SEBT predominately relies on a feedforward control strategy until contact is made with the toe touch.[20] By comparison the same report suggested that during the YBT, constant proprioceptive feedback is received as the reach-foot toe remains in contact with the reach-indicator throughout the excursion (feedback control).[20] Additionally, while the stance platform is relatively low, the slight elevation in stance position maintained during the YBT may also contribute to the decreased reach distance.[20] The other study[21] reported that the performance of the SEBT and YBT differed in relation to dynamic neuromuscular demands, as evident by the difference the anterior reach distances and associated kinematic profiles. For anterior reach, there was a negative correlation between reach distance and hip-joint sagittal-plane angular displacement for the SEBT (i.e., as hip joint flexion increased, reach

distance decreased). In contrast, there was a positive relationship between reach distance and hip-joint sagittal plane angular displacement during performance of the YBT (i.e., as hip joint flexion decreased, reach distance decreased).[21]

In addition to anterior direction differences, the results indicate that the reach distances for the posteromedial and posterolateral directions also differed between the mSEBT and the YBT. This is not consistent with the findings of the two reports noted above.[20,21] The sensorimotor system that regulates balance and postural awareness relies on information from the visual, vestibular and somatosensory subsystems.[33] When reaching in the anterior direction subjects receive visual feedback on their performance. However, in the posteromedial and posterolateral directions visual awareness is lower, which places a greater reliance on the non-visual somatosensory system. Coughlan et al.[20] reported that the reach distance achieved in the anterior direction was less for the YBT compared to the SEBT. When visual awareness was decreased in the posterior directions, a similar score was achieved between the SEBT and YBT. Their report suggested this increase in YBT performance relative to SEBT was due to the increased somatosensory feedback for the YBT due to the constant toe contact with the reach-indicator.[20] An important difference between the previous studies and the present investigation is the demographic characteristics of participants. Subjects in that study were healthy adult males 22.5 ± 3.05 years of age while this investigation assessed healthy adolescent females. Pubertal growth is reported to inhibit the sensorimotor functions of the lower extremity; thus, during dynamic postural control tasks adolescents heavily rely on visual cues.[34] The impaired non-visual somatosensory systems in adolescents may be the reason why the same increase in YBT performance relative to the SEBT is not demonstrated in our population. This may explain why performance in the posterior reach directions of the mSEBT and YBT were different for subjects in this investigation, yet were the same in an adult population.[20] Protocol variations in which testing in this investigation occurred during one session while these other two studies[20,21] conducted each dynamic balance test a week apart may

have also contributed to the differences observed in the posterior reach directions. The present results indicate that female adolescent subjects performed differently on both the SEBT and YBT assessment methods when compared to an adult population. Caution should be used when interpreting and comparing reach distance performance for adolescents to those achieved by adults.

In addition to the measured reach directions, a composite score was calculated for both the mSEBT and YBT. Bland-Altman analysis of the data indicated that for the anterior reach direction, the mSEBT distance was greater than YBT. However, the mSEBT reach distances were less than the YBT for both the posteromedial and posterolateral reach directions. Thus, when the composite score was calculated, the positively and negatively skewed reach values resulted in a value which was similar between the two tests. The inherent scoring differences in different reach directions, and possible differences in overall dynamic balance, are concealed when the assessment only includes the composite score values. Therefore, it is recommended that when assessing dynamic balance, participant performance on the individual reach directions should be analyzed, in conjunction with the calculated composite scores, as results of this investigation indicates that examination of only the composite score may not accurately reflect the true differences in dynamic balance performance for each test. Composite score values alone are often used in the literature to assess sport-specific risk of injury. A normalized SEBT composite score of less than 94.0% was shown to indicate the risk of a lower extremity injury in high school basketball players.[14] College football players who score less than 89.4% on the normalized YBT composite score are also at an increased risk of injury.[10] The average composite scores for our subjects were above both of these cut-off values for both the mSEBT and the YBT. Based on the above reported values for injury risk, mSEBT results indicated that five of the subjects were vulnerable to a lower extremity injury. For the YBT, only four subjects were at an increased risk of injury. Furthermore, only one individual was identified as susceptible to injury via both test cut-off values. The remaining at-risk individuals identified in the mSEBT were different from those identified in

the YBT, once again highlighting that a difference between the tests exists. This suggests that the sport-specific injury risk dynamic balance composite score cut-off values for high school basketball and college football players may not be accurate for physically active adolescent females.[13] Determination of such injury risk cut-off values for physically active adolescent females was beyond the scope of this study, and would be very useful for future application.

Asymmetries between limbs is also often used as a screening tool to determine those who may be at increased risk of sustaining an injury.[10,14] A difference in the raw anterior reach distance of more than 4cm between limbs for either the mSEBT[14] or the YBT[19] is clinically significant, and suggests a greater likelihood of sustaining a noncontact lower limb injury.[5,6,14,15,26] Recently, Stifler et al.[23] found that in Division I collegiate athletes' side-to-side asymmetry in the anterior reach direction of the SEBT was associated with injury. As dynamic balance scores vary based on age, sex and sport[13] it is unknown if this established injury risk cut-off value is appropriate for female adolescent athletes. This is the first report to compare injury risk classification based on limb asymmetry between the SEBT and YBT for the recreationally active female athlete. Analysis of raw anterior scores indicated that two subjects using the mSEBT and a different two subjects using the YBT had asymmetries of more than 4cm. Once again, results indicate that there is a difference between the two test methods for the specific population in this investigation. Further investigations of this population with a larger sample size are required to assess healthy and injured subjects to determine an appropriate cut-off value for each of the test methods.

Typically, clinicians will only complete one dynamic balance test as part of an evaluation. Both the mSEBT[14] and YBT[15] are reliable; as such, either test would be appropriate to assess dynamic balance in adolescent females, however the tests should not be used interchangeably. Each test protocol has its own strengths and limitations. The mSEBT does not require costly equipment and allows an evaluator to assess five reach directions in addition to the three used for the modified protocol. However the toe touch is harder to quantify and control in

the mSEBT. The instrumented YBT may provide quicker and more standardized measurements, it is limited to assessing only the anterior, posteromedial and posterolateral reach directions and may not be financially feasible for all clinicians. The goal of the present study was not to assess whether one test is superior to the other in assessing dynamic balance. The purpose was to evaluate whether the outcome factors of reach distance, composite scores and side-to-side limb asymmetry in the ANT direction of the mSEBT were interchangeable with those of the YBT, and to determine if previously reported thresholds determined in other populations would be accurate when classifying adolescent female athletes at-risk of injury. Although most test scores were found to have a moderate positive correlation between the two test methods based on Pearson product-moment correlations, t-test results showed that the absolute values of the mSEBT reach directions are not interchangeable with the absolute reach values of the YBT. This means that if a subject had a high reach distance on the mSEBT, they would also have a high score when performing the same reach direction on the YBT. But a reach distance score of 94% on the mSEBT, was not the same as a reach distance of 94% on the YBT. Subjects are inconsistently classified as at-risk for an injury when using the previously established cut-off value of greater than 4 cm asymmetry in the anterior reach direction. Researchers and clinicians should be aware of these inherent differences when interpreting and implementing these dynamic balance tests.

It is important to acknowledge that this study did have several limitations, primarily related to the specific population which limits the external validity, but addresses an important deficiency in the literature regarding clinical dynamic balance tests for this population. While several sport-specific reports examined the mSEBT and YBT in female athletes, the diverse group of sporting activities of subjects in this investigation allows commentary on a more broad-based population of athletes. This population is of particular interest to clinicians as athletically active adolescent females are at a high-risk of sustaining lower extremity injuries. A priori power analysis indicated that our sample size was appropriate to assess the measured reach distances of dynamic

balance tests,[15,26] however sample size was a limitation for the composite score and absolute side-to-side limb asymmetry. While future studies will need a larger sample size to establish normative values for both healthy and injured physically active adolescent females, this investigation is the first to report dynamic balance scores for a recreationally active adolescent female population, drawn from a diverse sporting population. Importantly, placement of the stance limb foot varies between the mSEBT and YBT: in the mSEBT, the heel is aligned to the center of the mSEBT grid,[1] and for the YBT, the toes of the stance limb are aligned to the center of the grid. Differences in the anterior reach distances between the tests may be directly related to this variation. In future studies comparing the test procedures, the mSEBT should adapt the standardized foot position of the YBT.

CONCLUSION

The results of this study suggest that although both the mSEBT and YBT can be used clinically to measure dynamic balance, performance scores on a particular reach direction should not be used interchangeably between the mSEBT and YBT in this population. Since administration of the mSEBT and YBT protocols varies within the literature, specific detailed methodology should be carefully reviewed by clinicians and researchers when interpreting dynamic balance scores and using cut-off values to classify individuals at-risk of injury. Further research is clearly needed in order to establish normative values for the SEBT and YBT in the adolescent female population, and determine the limits of reliability for dynamic balance testing in healthy and ACL-injured individuals.

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